**SCH 3U**

# MOLECULAR, IONIC & NET IONIC EQUATIONS

When **two compounds in aqueous solutions** are mixed and allowed to react, ions change partners – this reaction is known as a **DOUBLE DISPLACEMENT** reaction. If ions can be removed from solution, then a reaction occurs and one of the following may be observed:

① **PRECIPITATE forms**
- mixing of two solutions forms an insoluble compound

② **GAS forms**
- bubbles or odour escapes from reaction mixture

③ **NEUTRALIZATION**
- **mix of aqueous acids and bases forms soluble salt and water**.
- Measuring pH or concentration of a substance in the mixture is evidence of the changes occurring in the mixture.

④ **WEAK ELECTROLYTE forms from solutions of strong electrolytes**.
- Formation of a soluble compound that is a nonelectrolyte, like water, or a weak electrolyte, like a weak acid.

Regardless of the type of reaction, the use of **IONIC EQUATIONS** and **NET IONIC EQUATIONS** illustrates the reaction that is occurring in the aqueous mixture.

- Soluble strong electrolytes are written in **ionic form** to show their **dissociation**
- Precipitate or gas is written in **molecular (or compound) form** since its ions that make up the solid/gas are not wandering free through the solution.

## DISSOCIATION OF IONIC SUBSTANCES IN AQUEOUS SOLUTIONS:

**EXAMPLES:**

1. $(NH_4)_2SO_{4(aq)} \rightarrow 2\ NH_4^{+}{}_{(aq)} + SO_4^{2-}{}_{(aq)}$

2. $BaCl_{2(aq)} \rightarrow$

3. $NaNO_{3(aq)} \rightarrow$

4. $Cu_2SO_4 \cdot 5H_2O_{(s)} \xrightarrow{H_2O}$

## ① PRECIPITATE FORMS:

[SEE TABLE 9.1 on PAGE 334 for Solubility Rules]

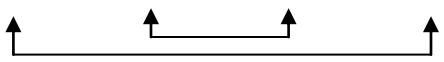
- If substance is soluble in water, it remains dissolved in water and exists as ions.
- If substance is ***insoluble***, the undissociated form (or molecular form) of the substance is written in both ionic and net ionic equations.

- The **precipitate** (solid) can be separated and recovered from the mixture of products by **filtering**, using filter paper.
- The remaining solution that passes through the filter paper is called the **filtrate**.

**EXAMPLE:** Consider the mixing of ammonium sulfate and barium chloride solutions:

$(NH_4)_2SO_{4(aq)} + BaCl_{2(aq)} \rightarrow$

$2\ NH_4^+{}_{(aq)} + SO_4^{2-}{}_{(aq)} + Ba^{2+}{}_{(aq)} + 2\ Cl^-{}_{(aq)} \rightarrow$



$(NH_4)_2SO_{4(aq)} + BaCl_{2(aq)} \rightarrow \underline{BaSO_4 + NH_4Cl}$

[potential products from interchanging the ions of the reactants]

To determine the products (assuming a reaction occurs), write the reactants in their ionic form (ionic equation) since they are in aqueous solutions. Interchange the ions of the 2 original compounds and complete the molecular equation without indicating their states. Be mindful of the charges of the ions when writing formulas of the products.

To determine the states, consult the Solubility Rules in Table 9.1. $BaSO_4$ is insoluble, meaning that it will precipitate from the mixed solutions, whereas the $NH_4Cl$ is soluble. The final balanced molecular equation will be as follows, including the ionic and net ionic equations:

$(NH_4)_2SO_{4(aq)} + BaCl_{2(aq)} \rightarrow BaSO_{4(s)} + 2\ NH_4Cl_{(aq)}$ **[molecular equation]**

$2\ NH_4^+{}_{(aq)} + SO_4^{2-}{}_{(aq)} + Ba^{2+}{}_{(aq)} + 2\ Cl^-{}_{(aq)} \rightarrow 2\ NH_4^+{}_{(aq)} + 2\ Cl^-{}_{(aq)} + BaSO_{4(s)}$ **[ionic equation]**

$SO_4^{2-}{}_{(aq)} + Ba^{2+}{}_{(aq)} \rightarrow BaSO_{4(s)}$ **[net ionic equation]**

## ② GAS FORMS:

- In a double displacement reaction, if any of the following products are formed, they have either a low solubility in water (and will escape the mixture as a gas or are insoluble and unstable and will break down into water and a gas:

***TO MEMORIZE:***

$H_2CO_3 \rightarrow H_2O + CO_2$

$H_2SO_3 \rightarrow H_2O + SO_2$

$NH_4OH \rightarrow H_2O + NH_3$

## ③ NEUTRALIZATION:

- Acid + Base → Salt + Water

**EXAMPLE:** sulfuric acid is mixed with sodium hydroxide

$H_2SO_{4(aq)} + 2\ NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + 2\ H_2O_{(l)}$

$2\ H^{1+}_{(aq)} + SO_4^{2-}{}_{(aq)} + 2\ Na^{1+}_{(aq)} + 2\ OH^{1-}_{(aq)} \rightarrow 2\ Na^{1+}_{(aq)} + SO_4^{2-}{}_{(aq)} + 2\ H_2O_{(l)}$

$2\ H^{1+}_{(aq)} + 2\ OH^{1-}_{(aq)} \rightarrow 2\ H_2O_{(l)}$ **[net ionic equation]**

## ④ WEAK ELECTROLYTE FORMS:

- A strong acid is mixed with a salt that contains an anion of a weak acid.
- Products of such a reaction are a ***soluble salt*** and an ***insoluble weak electrolyte***.

**EXAMPLE:** Consider the mixing of hydrochloric acid and sodium acetate:

$HCl_{(aq)} + NaC_2H_3O_{2(aq)} \rightarrow NaCl_{(aq)} + HC_2H_3O_{2(aq)}$ [molecular equation]

- All of the solutes are strong electrolytes except $HC_2H_3O_2$, which is a weak acid (weak electrolyte). It remains molecular, and not ionic, in solution.

$H^+_{(aq)} + Cl^-_{(aq)} + Na^+_{(aq)} + C_2H_3O_2^-{}_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)} + HC_2H_3O_{2(aq)}$

$H^+_{(aq)} + C_2H_3O_2^-{}_{(aq)} \rightarrow HC_2H_3O_{2(aq)}$

## WRITING NET IONIC EQUATIONS:

① Write the balanced molecular equation.

② Write **aqueous** ionic compounds in their dissociated form. ***Compounds which are present in solid, liquid or gas state remain in their molecular form.***
[Acids are classified as aqueous solutions, and are written in dissociated form.]

④ Cancel **spectator ions** – aqueous ions appearing on both sides of the ionic equation.

⑤ Write the net ionic equation.

## ***NOTE:***

- ***MOLECULAR EQUATIONS*** are useful as they identify the actual reactants and products and their stoichiometric amounts.

$$AB_{(aq)} + CD_{(aq)} \rightarrow CB_{(aq)} + AD_{(s)}$$ [precipitate AD is formed]

- ***IONIC EQUATIONS*** are useful for visualizing all that is happening in the solution when the reaction is taking place.

$$A^+_{(aq)} + B^-_{(aq)} + C^+_{(aq)} + D^-_{(aq)} \rightarrow C^+_{(aq)} + B^-_{(aq)} + AD_{(s)}$$

- ***NET IONIC EQUATIONS*** are useful when we want to generalize the reaction – that is, more than one set of reactants can lead to the same net reaction.

$$A^+_{(aq)} + D^-_{(aq)} \rightarrow AD_{(s)}$$

***NOTE:*** If 2 solutions are mixed and no reaction occurs, then all ions remain aqueous and no net ionic reaction can be written. When cancelling the common ions from both sides of the ionic reaction, no ions remain, so no reaction occurs.

**EXAMPLES:** Write molecular, ionic and net ionic equations for each reaction.

1. Aqueous magnesium chloride mixed with aqueous potassium hydroxide.

2. Aqueous lead (II) nitrate mixed with aqueous potassium iodide.

3. Aqueous ammonium nitrate mixed with aqueous potassium hydroxide.